TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 257

# TECHNICAL PREPARATION OF THE AIRPLANE "SPIRIT OF ST. LOUIS"

Written for the National Advisory Committee for Aeronautics

By Donald A. Hall
Chief Engineer, Ryan Airlines, Inc.



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In order to clarify the current impressions as to the technical preparation, in connection with both the design and performance, of the airplane used by Colonel Charles A. Lindbergh, the following information is presented.

The development of this airplane was begun with the idea of using a standard model Ryan M-2 and making modifications to suit the special purpose. Upon Colonel Lindbergh's arrival at the factory, it was quickly determined that modification of the M-2 was less practicable than redesign. Colonel Lindbergh laid out the following basic specifications: That the airplane should be a monoplane type, powered with a single Wright J-5-C engine, have a good power reserve on take-off when carrying more than 400 gallons of gasoline and must have the pilot located in rear of all tanks for safety in a forced landing.

The decision on these basic specifications immediately determined the inadvisability of using the standard Ryan M-2 model. The airplane was then laid out anew, the fuselage following the standard model approximately in regard to design and structure, but being lengthened by 2 feet. The fuselage structure was redesigned to suitable load factors in flight and landing with full load. A wide tread split axle chassis was designed to a four load factor at full designed load. The wing structure was designed to suitable load factors in high incidence, low incidence, and diving conditions at full designed load.

At this point Colonel Lindbergh began to take a very active interest in the design of the airplane, and until the airplane had completed its flight tests he closely cooperated with the engineering department of the Ryan Company. The location of the pilot's cockpit (cabin) in the rear of the fuselage and entirely enclosed, which is the most radical feature of the design, had its development based on the primary requisite of safety, it being considered that in the event of an accident the pilot would be in the safest position in which it would be possible to be placed.

The periscope was suggested by Mr. Randolph, of the Ryan Airlines, who had had considerable submarine experience. This suggestion was accepted by Colonel Lindbergh with the limitation that if it was not satisfactory or was of any aerodynamical disadvantage it would be discarded at New York. The periscope consisted of a panel in the instrument board (shown in the illustration) through which a view directly to the front was afforded by an angular mirror, having a frontal size of about 3 by 5 inches, which projected from the left side of the fuselage, and which could be retracted when not in use. The device proved of no disadvantage aerodynamically on account of the retractable feature, and was of certain utility during the flights of the airplane.

The engine, to ensure proper balance, was of necessity moved forward considerably. The additional space in the forward part of fuselage which was provided by this extension was utilized for the oil tank, located directly in the rear of the engine and a gasoline tank in the rear of the oil tank. The oil and tank provided an excellent fire wall. It was found that with full load the two tanks, although so far forward, did not interfere with the trim of the airplane to an extent which could not readily be taken care of by the adjustable stabilizer.

All of the various items of design had very careful consideration, in which Colonel Lindbergh took a prominent part. The interest shown by him in the detailed design and construction of the airplane was in no way a critical interest.

Colonel Lindbergh's time was further occupied during the period in which the airplane was under construction in a careful and intensive study of navigation. This study was most complete. During four weeks practically all his waking hours were occupied by this study of navigation and the preparation of charts and data for use in a dead reckoning flight. It should be borne in mind that he had practically no technical knowledge of the art of navigation prior to this time with the exception of such aerial navigation as he had had in his Army and Air Mail experience.

Members of the Ryan Airlines factory organization who were responsible for the construction of the airplane are Mr. B. F. Mahoney, President of the Company, Mr. W. H. Bowlus, Factory Manager, Mr. Bert Tindale, Shop Superintendent, and in charge of wing department, Mr. Walter Locke, in charge of Purchasing Department, who also assisted in engineering, Mr. McNeal, in charge of Final Assembly Department, Mr. Fred Rohr, in charge of Tank and Cowling Department, Mr. Fred Ayers, in charge of Covering and Finishing Department, Mr. Anderson, in charge of Welding Department, Mr. Morrow, in charge of Fitting Department, in addition to the writer.

Colonel Lindbergh paid close attention to the final assembly securing a thorough practical knowledge of the major units, especially the fuel system.

Immediately upon the completion of assembly, the flight tests were begun, the preparation for which had been made in detail. Colonel Lindbergh had laid out with the writer the tests to be made, and all of the test flights were flown by Colonel Lindbergh himself, who is the only pilot who has ever flown this airplane.

A program of tests was carried out which was sufficiently comprehensive to check the theoretical performance. A series of flights with fuel loads of from 36 to 300 gallons was made for the specific purpose of checking take-off distances.

All of these flight tests were made for the primary purpose of checking the theoretical figures as to performance, and while not as comprehensive as might have been possible had more time been available, were sufficient in the opinion of Colonel Lindbergh.

It is hoped that from these few paragraphs it will be understood that the ultimate performance of the "Spirit of St. Louis" is largely the result of the exceptionally careful and painstaking effort on the part of Colonel Lindbergh in his preparations while at San Diego, and that his evident confidence in the Ryan Airline organization was merited. It is the belief of the writer that Colonel Lindbergh did not leave San Diego until he was absolutely certain that he had an airplane with which the transatlantic flight was possible, and that this conclusion was reached after a tremendous volume of work which he set for himself and accomplished while at the Ryan Airlines factory.

## Modifications of Construction

In order to sustain the increased loads resulting from the full load required for the New York to Paris flight, it was necessary to increase the wing span by 10 feet and to redesign all the structural members of the wing cellule and fuselage. The wing ribs were more closely spaced (11 inches on centers) and plywood was fitted on the leading edge of the wing running from the top of the front spar around to the bottom of the spar. On account of the increased moment arm the ailerons were reduced in area and were located inboard from the wing tips. This was expected to reduce wing tip deflection and give better aerodynamic efficiency. The wing tips, in plan form, were given an airfoil contour.

To suit the increased wing span and for increased safety the landing gear was given a wider tread. Dual axles (front and rear integral) made of chrome molybdenum steel tubing heat-treated to 180,000 lb./sq.in., were used. The shock absorber was of trombone type with 8 individual links of cord and a $6\frac{1}{2}$-inch rise.

The tail surfaces were practically the same as those of the M-2 but were installed 2 feet farther aft on the lengthened fuselage. The streamlining of the fuselage was entirely new and was worked out so that any longitudinal section of the fuselage gives a smooth curve from propeller spinner to tail. A fillet streamline was used at the junction of the bottom of the wing and the fuselage.

The tail skid was made of heat-treated chrome molybdenum steel tubing of the same quality as the axles.

The power plant consisted of a single Wright J-5-C engine, a stock model. The tanks for oil and gasoline were all of terneplate. The three wing gasoline tanks together had a capacity of 152 gallons, the center fuselage tank 210 gallons, and the forward fuselage tank 88 gallons. The designed gasoline capacity was 425 gallons. It came out 450 gallons.

All the gasoline tanks connected to a Lunkenheimer distributer in the pilot's cabin and it was possible to pump from any tank to any other. There were two fuel systems to the engine. In addition to the other instruments, an econometer invented by Colonel Lindbergh was used on the fuel system.

The 25-gallon oil tank was arranged between pilot and engine so as to act as a fire wall.

General Dimensions and Specifications

of the Airplane are as follows:

General -

| | |
|---|---|
| Span | 46 ft. |
| Chord | 7 " |
| Wing area | 319 sq.ft. |
| Airfoil | Clark Y |
| Engine, Wright J-5-C, giving 223 B.HP. at 1800 R.P.M. | |
| Propeller, Standard Steel Propeller Co., dural. set at | 16-1/4 pitch |

Weights -

| | | |
|---|---|---|
| Empty, complete with instruments | | 2150 lb. |
| Useful load: | | |
| Pilot | 170 lb. | |
| Miscellaneous | 40 " | |
| Gasoline, 425 gal. (Western at 6.12 lb. per gal.) | 2600 " | |
| Oil, 25 gal. (at 7 lb. per gal.) | 175 " | |
| | | 2985 lb. |
| Gross weight fully loaded at start of flight | | 5135 " |
| Gross weight lightly loaded at end of flight without gasoline and food but with 10 gal. of oil left | | 2415 " |

Loading -

Wing loading (Full load at start of flight = 16.10 lb./sq.ft.
(Light load at end of flight = 7.57 "

Power loading (Full load at start of flight = 23.0 lb./B.HP.
(Light load at end of flight = 10.8 "

General Dimensions and Specification (Cont.)

Calculated Performance (R.P.M. data based on test and theory) -

| | | |
|---|---|---|
| Maximum speed | (Full load | = 120.0 M.P.H. |
| | (Light load | = 124.5 " |
| Minimum speed | (Full load | = 71 " |
| | (Light load | = 49 " |
| Economic speed | (Full load | = 97 M.P.H. at 1670 R.P.M. |
| | (Light load | = 67 " " 1080 " |

Fuel Economy at Economic Speeds -

Full load with full rich mixture = 6.95 miles per gallon.

Light load with lean mixture = 13.9 " " "

Range -

At ideal speeds of 97 start and 67 M.P.H. at end = 4110 mi.

At practical " " 95 " " 75 " " " = 4040 "

Flight Test Performance -

Maximum speed:
With 25 gal. gas & 5 gal. oil = 129 M.P.H. over 3 km course

With full load of 425 gal. gas & 25 gal. oil ......... = 124 M.P.H. approximate based on calculated performance.

With 25 gal. gas & 4 gal. oil by air-speed meter = 128 "

With 201 gal. gas & 4 gal. oil by air-speed meter = 127 "

General Dimensions and Specifications (Cont.)

Take-Off Distances--

Tests made at Camp Kearney near San Diego, California, at 600 ft. altitude. Oil = 4 gallons.

| Gal. Gas | Gross Wt. lb. | Approx. Head Wind Velocity M.P.H. | Take-Off Distance ft. |
|---|---|---|---|
| 36 | 2600 | 7 | 229 |
| 71 | 2800 | 9 | 287 |
| 111 | 3050 | 9 | 389 |
| 151 | 3300 | 6 | 483 |
| 201 | 3600 | 4 | 615 |
| 251 | 3900 | 2 | 800 |
| 301 | 4200 | 0 | 1023 |

## Weight Characteristics when Ryan NYP Left New York

| | | |
|---|---|---|
| Empty complete with tanks and instruments . . . . . . | | 2150 lb. |
| <u>Useful load</u>: | | |
| Pilot | 170 lb. | |
| Miscellaneous | 40 " | |
| Gasoline, 450 gal. (California at 6.12 lb./gal.) . . . . . . . . | 2750 " | |
| Oil, 20 gal. at 7 lb./gal. | 140 " | |
| | | 3100 lb. |

<u>Gross Weight</u> -

Fully loaded (25 gal. gasoline over design load) . . 5250 lb.

<u>Net Empty Weight</u> -

Empty weight of 2150 lb. includes all tanks and special equipment and instruments.

Assuming a gas capacity of 60 gallons and oil of 5 gallons sufficient for ordinary flying, the weight of excess tanks and special equipment and instruments equals 450 lb.

Net empty weight = 2150 - 450 = 1700 lb.

<u>Total Useful Load</u> -

Total useful load = 5250 - 1700 = 3550 lb.

<u>Ratio of Weights</u> -

Ratio of useful load to gross weight = .68

Gross weight = 3.1 times net empty weight.

<u>Loading (Fully Loaded)</u> -

Wing loading = 16.5 lb. per sq.ft.

Power loading = 23.6 lb. per B.HP. (223 B.HP. at 1800 R.P.M.).

Airplane structure designed to suitable load factors at full design load.

Man Hours to Build Ryan NYP Airplane

Construction -

3000 man hours to build not including superintendent's and manager's time.

Engineering -

775 hours by designer, including performance calculations and flight testing.

75 hours put in by men in other departments (man hours).

850 man hours total engineering time between February 26 and May 10, when NYP left San Diego for St. Louis.

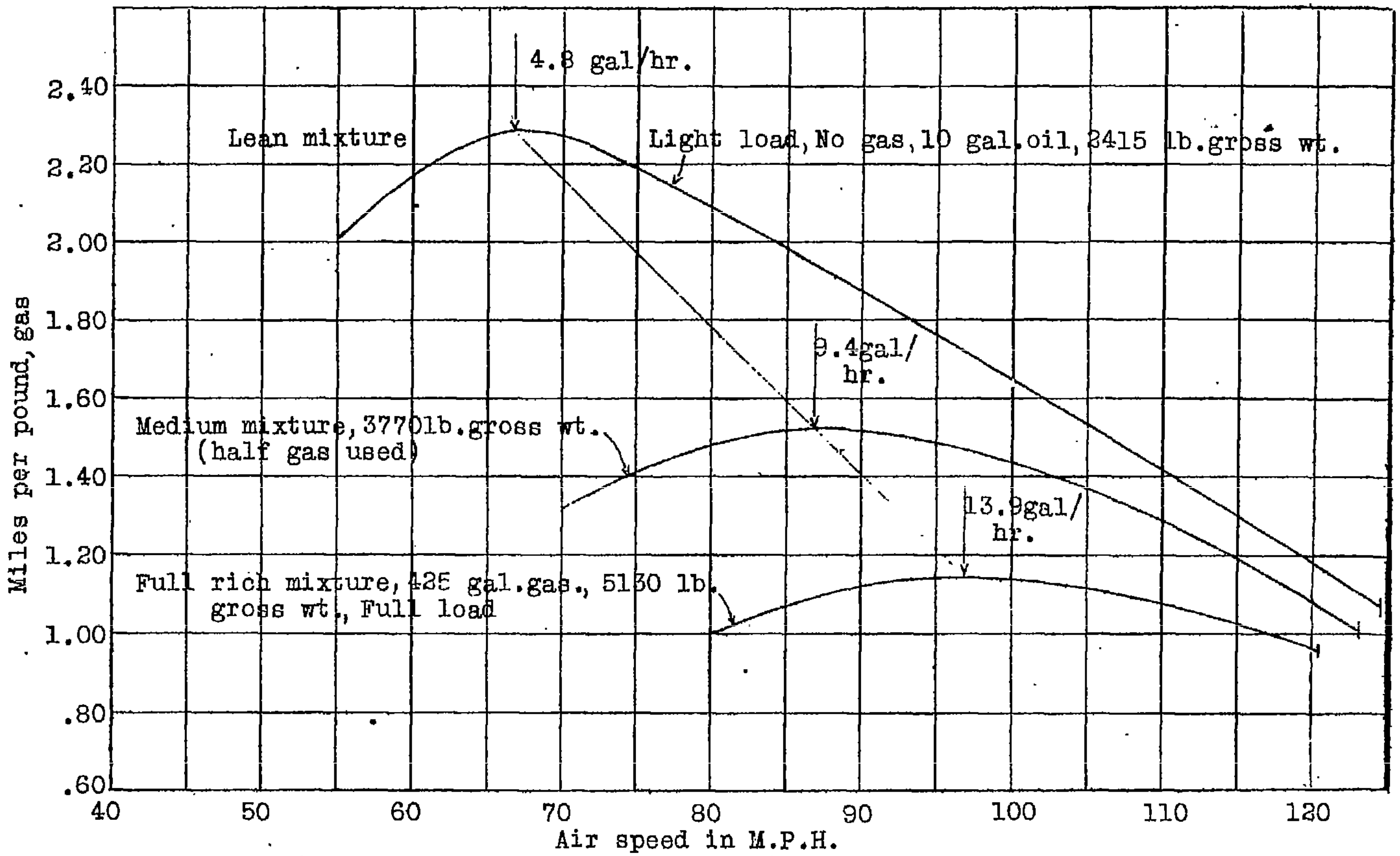


Fig.1 Fuel economy, Ryan NYP airplane

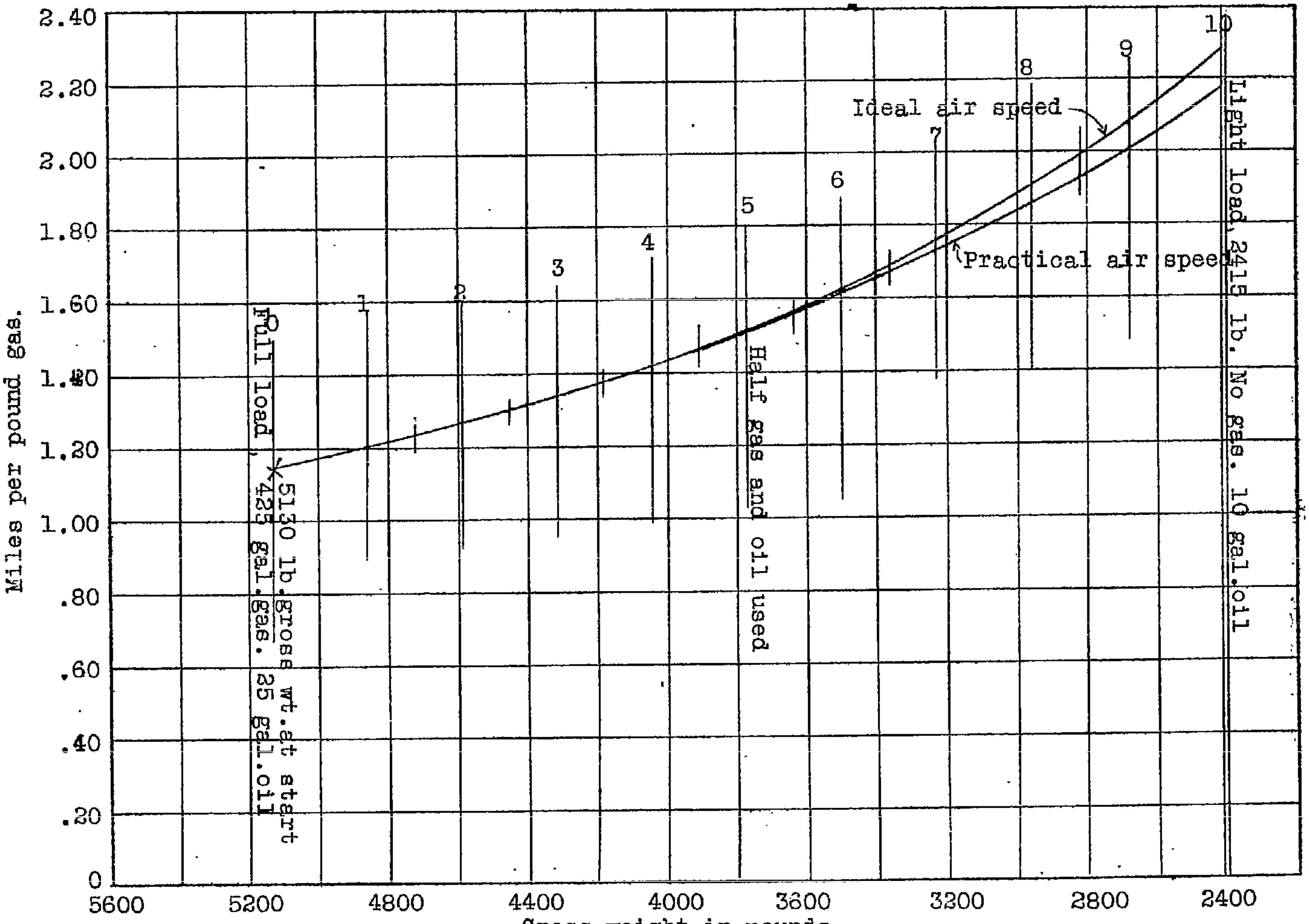


Fig.2 Ryan NYP airplane.

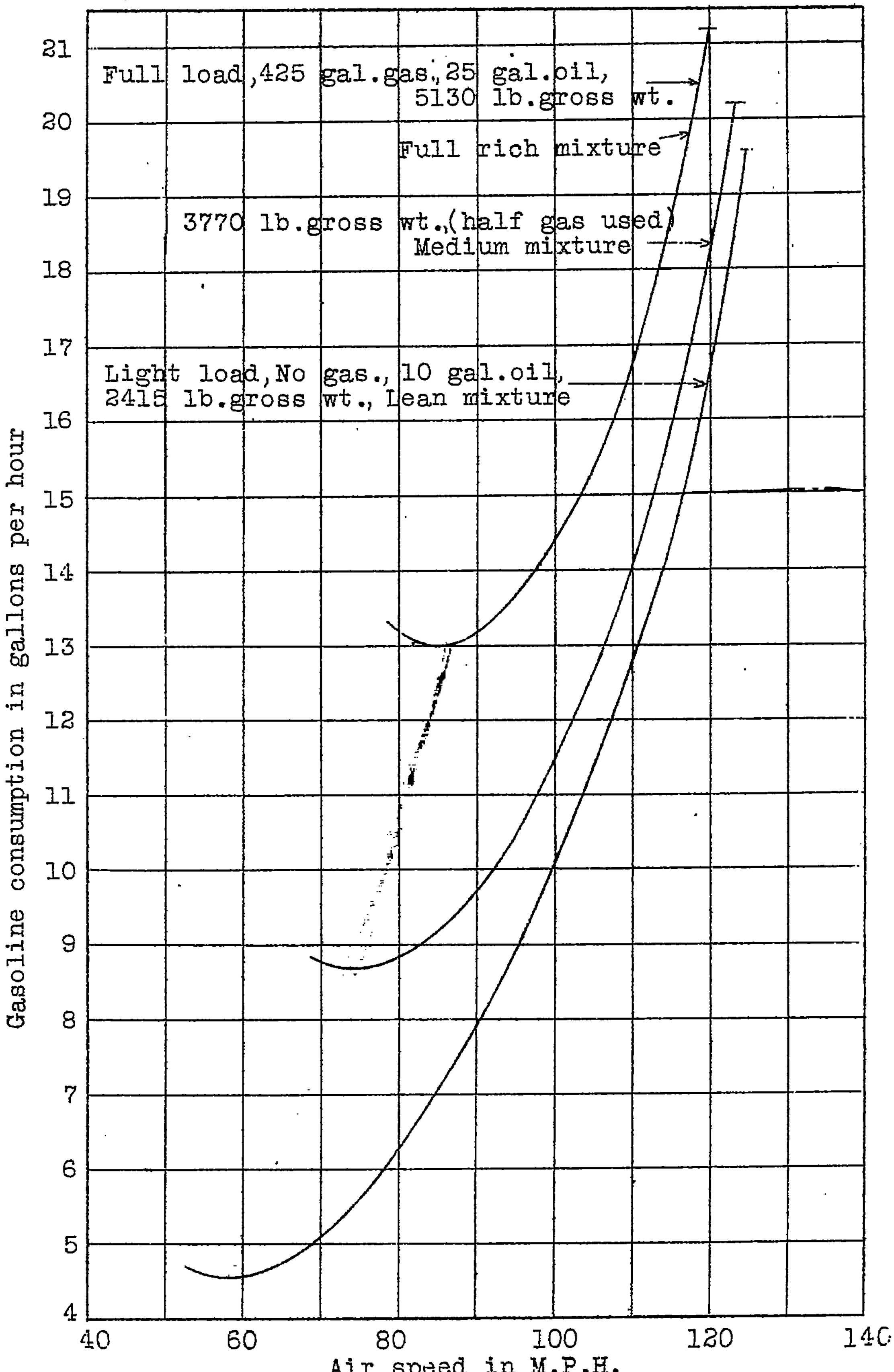


Fig.3 Western gasoline at 6.12 lb. per gal. weight used. Ryan NYP airplane.

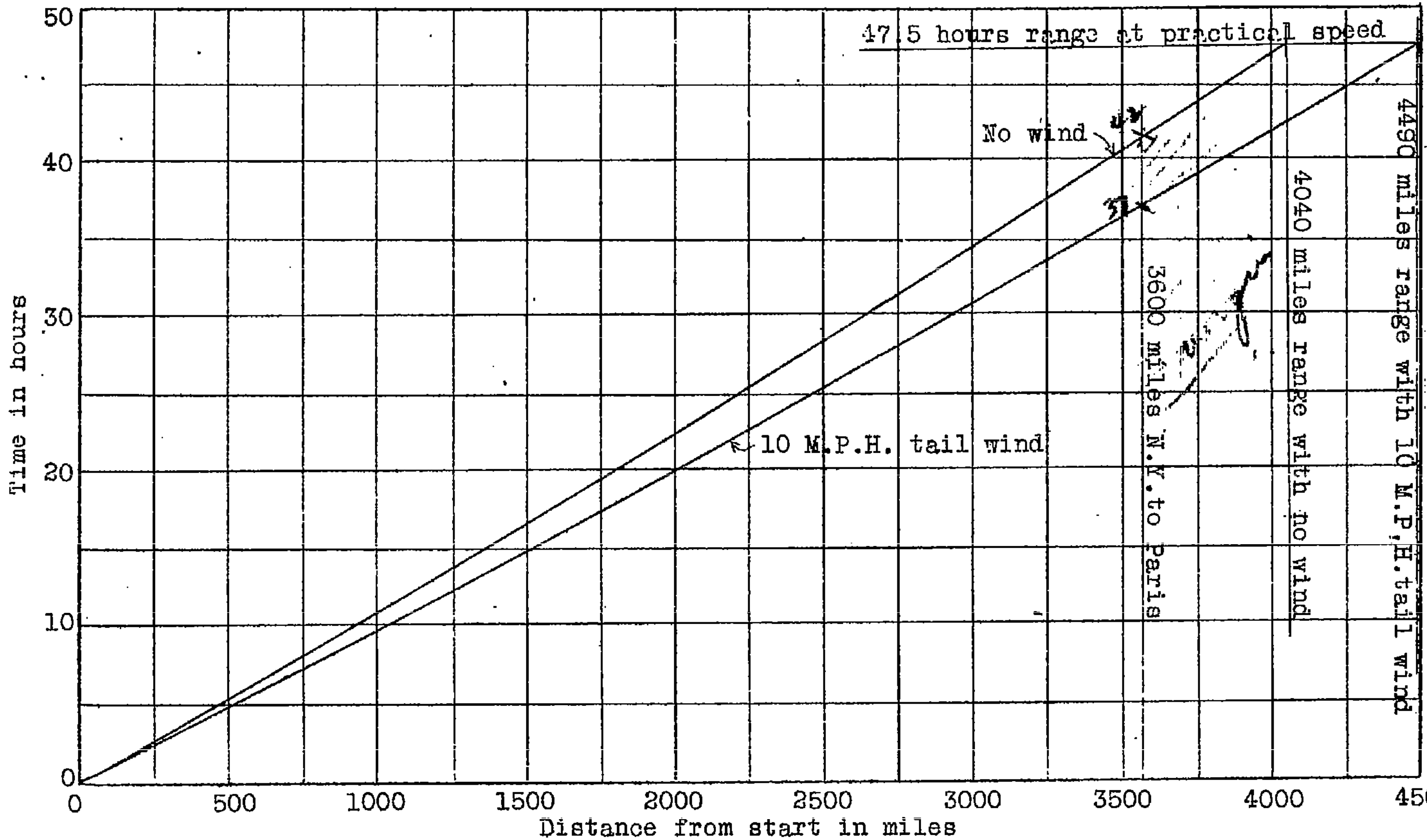


Fig.4 Ryan NYP airplane.

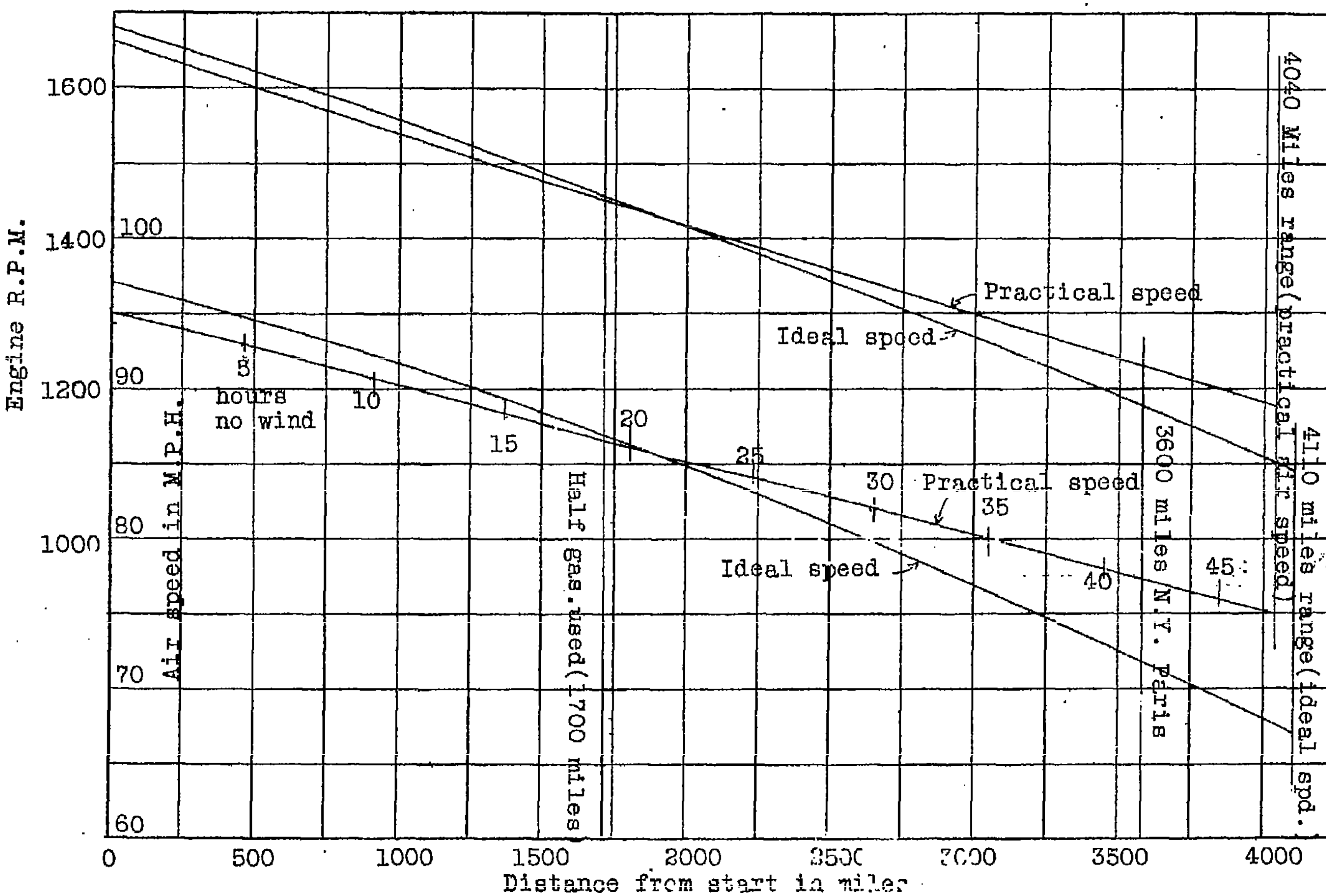


Fig.5 Ryan NYP airplane.

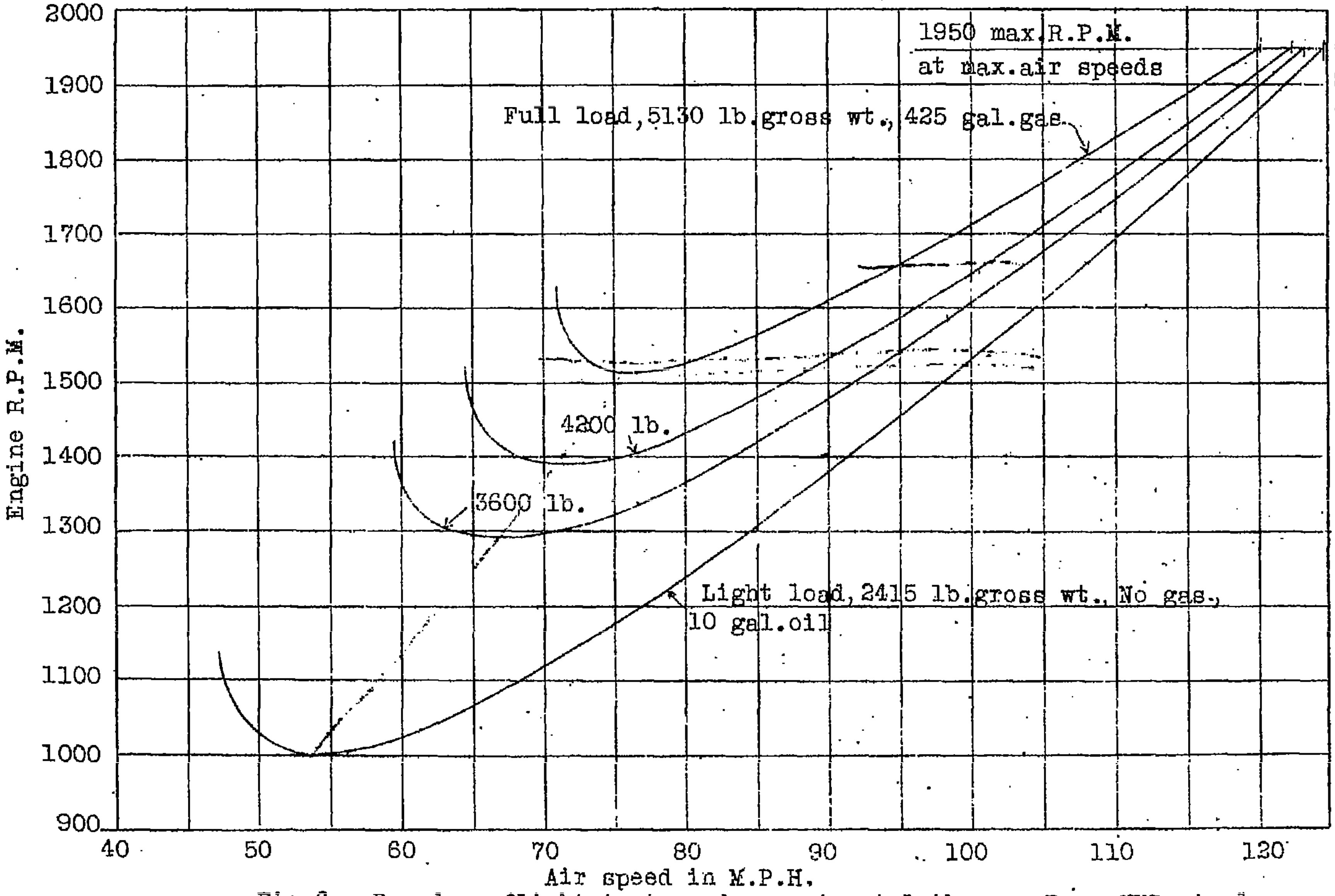


Fig.6 . Based on flight tests and experimental theory. Ryan NYP airplane.

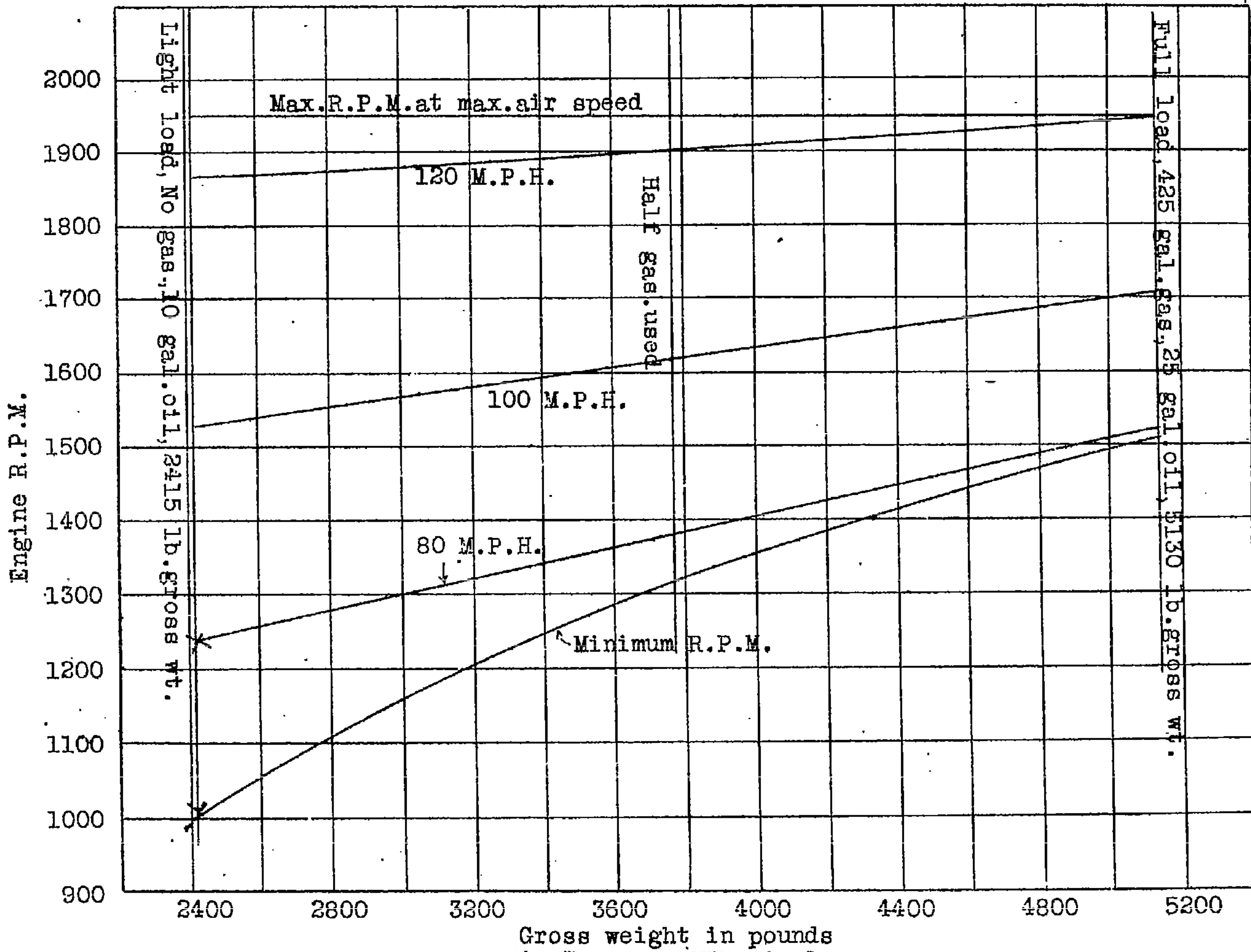


Fig.7 Ryan NYP airplane.

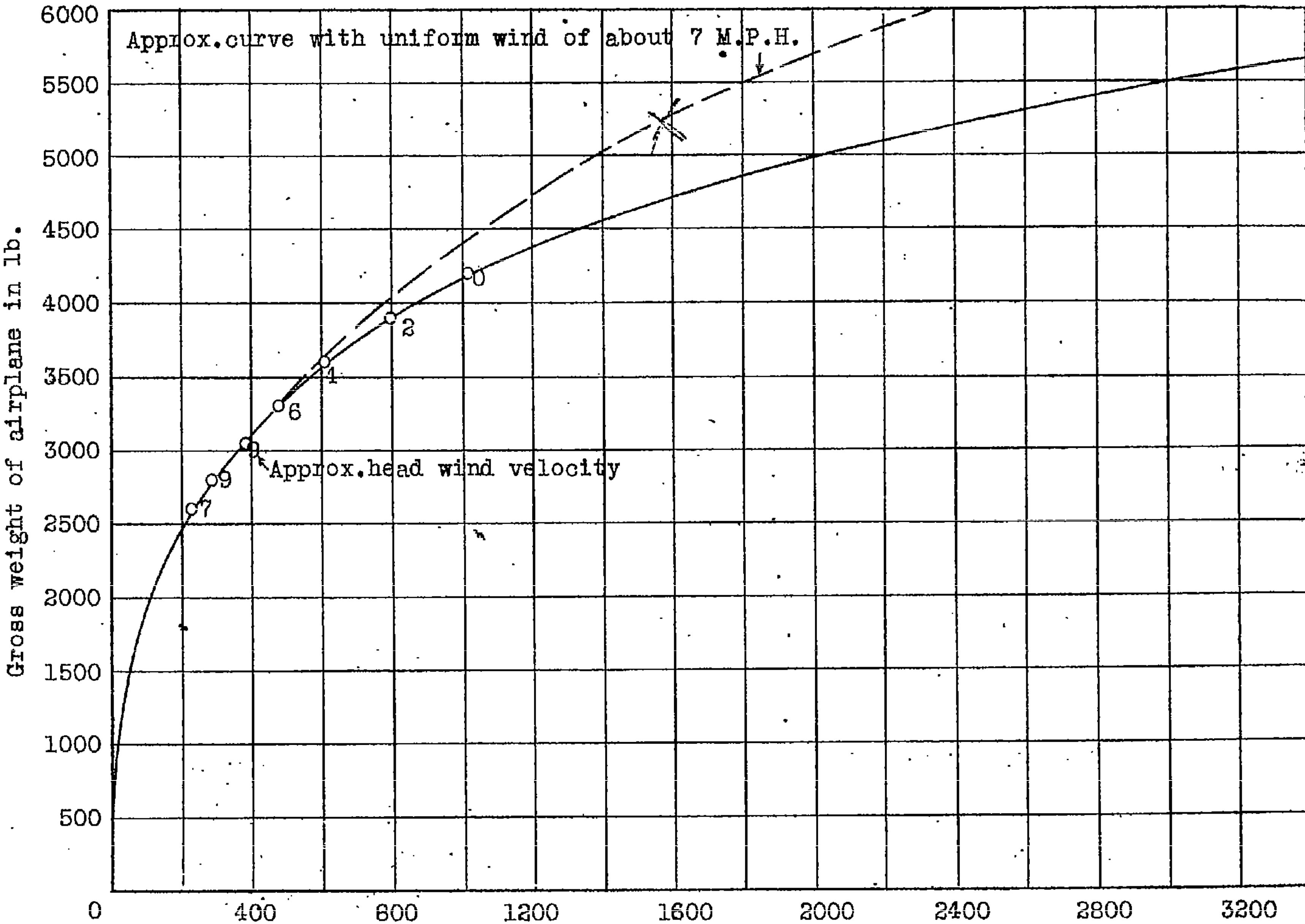


Fig.8 Take off tests. Altitude of field 600 ft. Ryan NYP airplane.

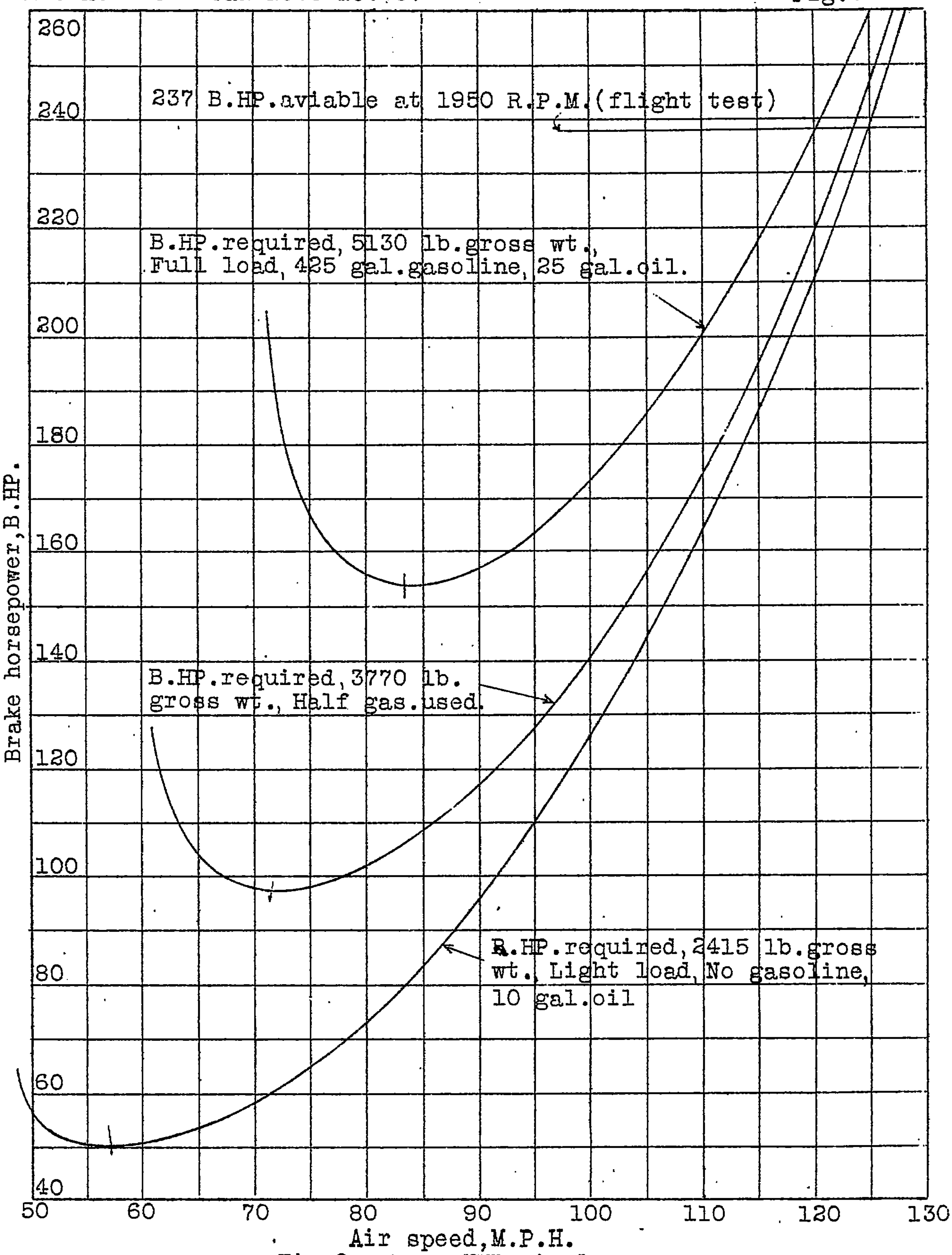


Fig.9 Ryan NYP airplane.

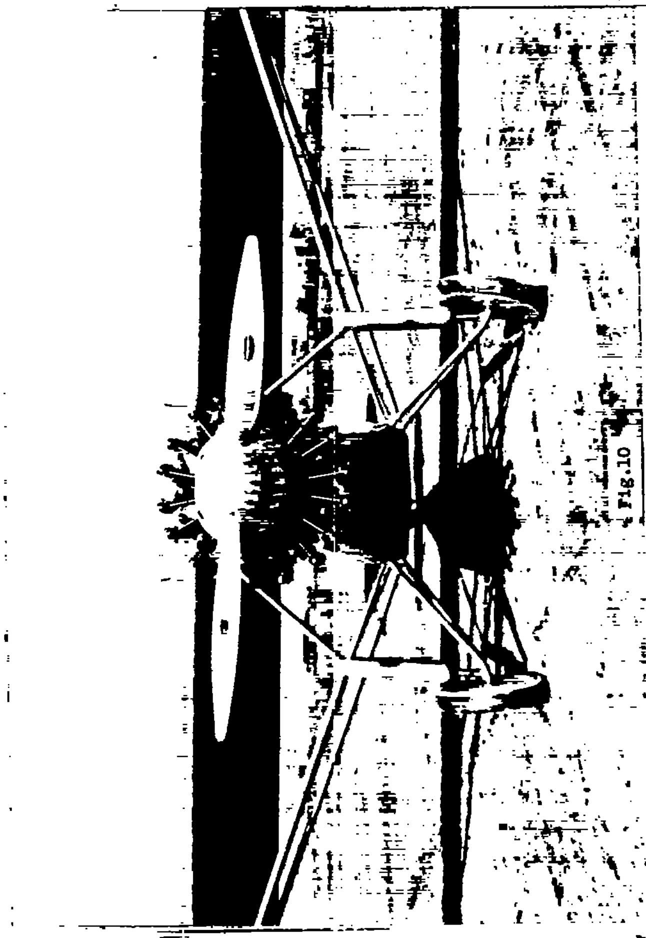

Fig.10

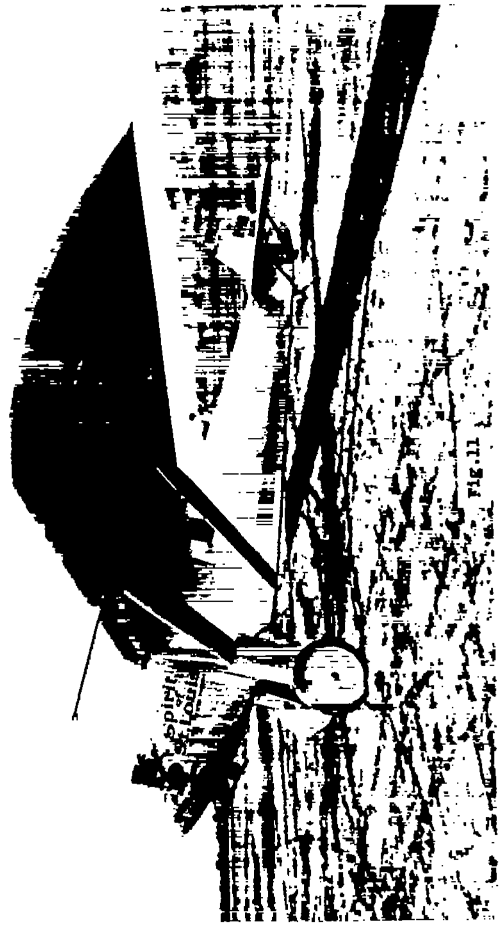

Fig.11

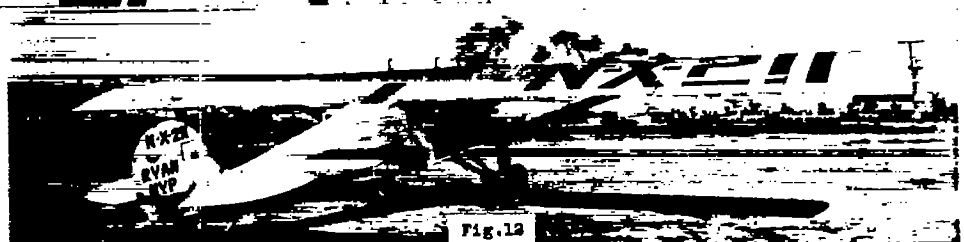


Fig.12

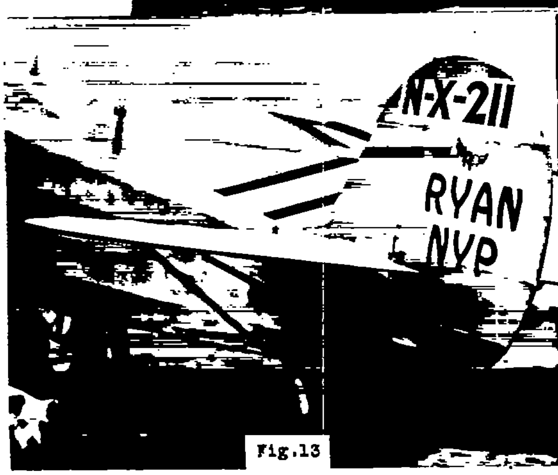


Fig.13


Fig.14

7479 A.S.

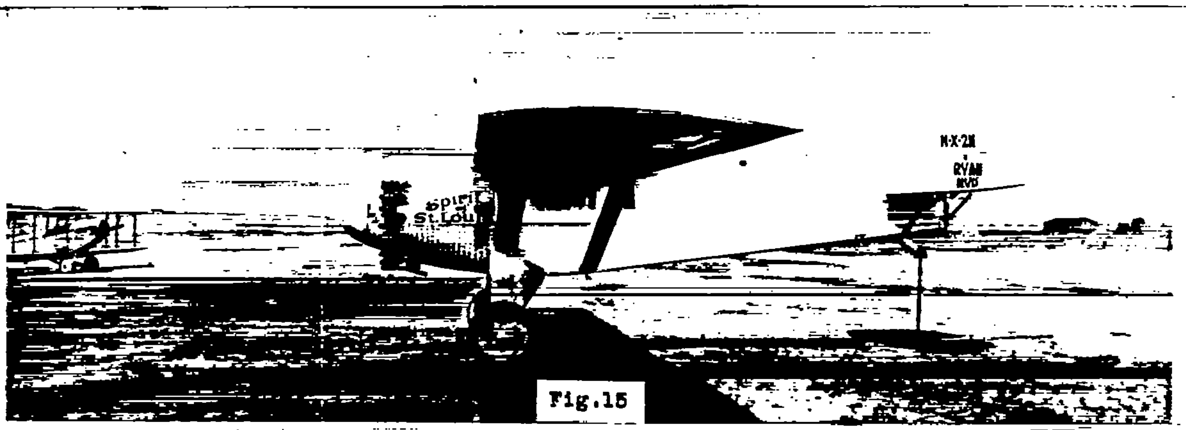


Fig.15

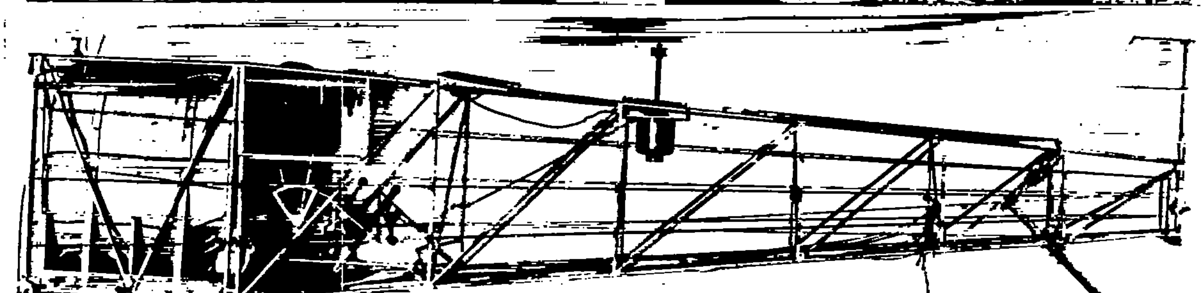

Fig.16

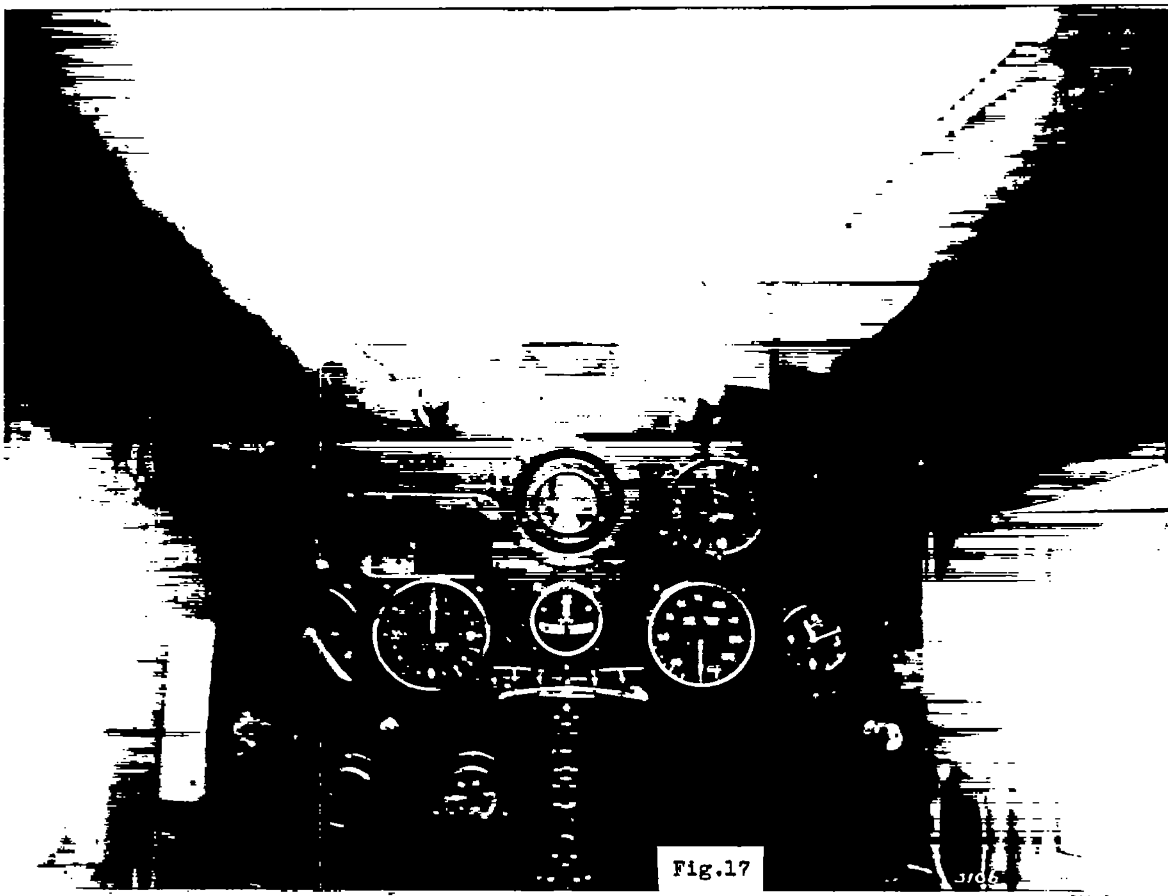

Fig.17

7475 R.S.

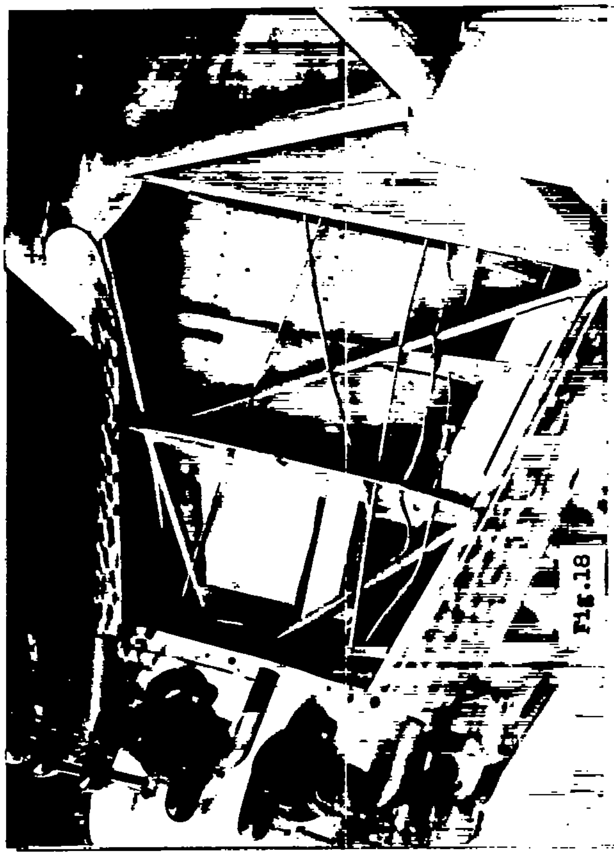

Fig.18

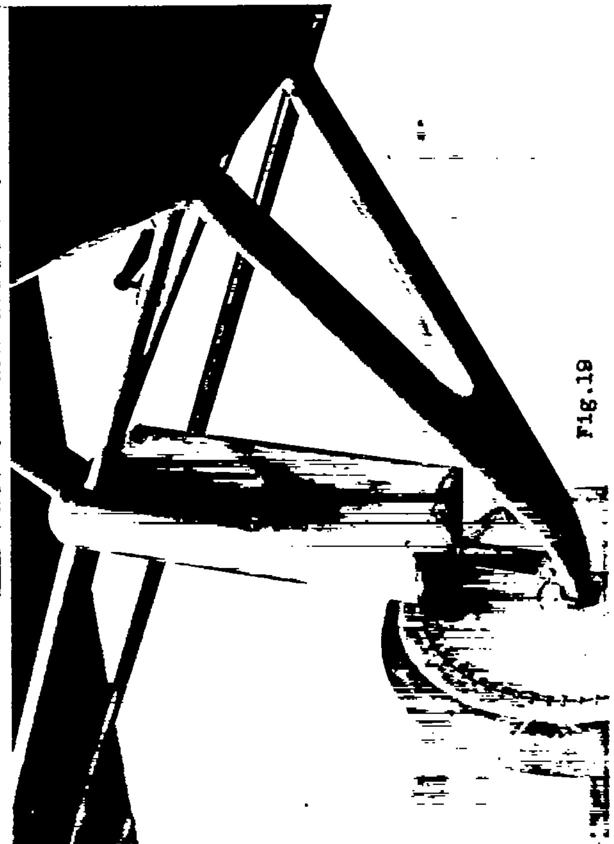

Fig.19

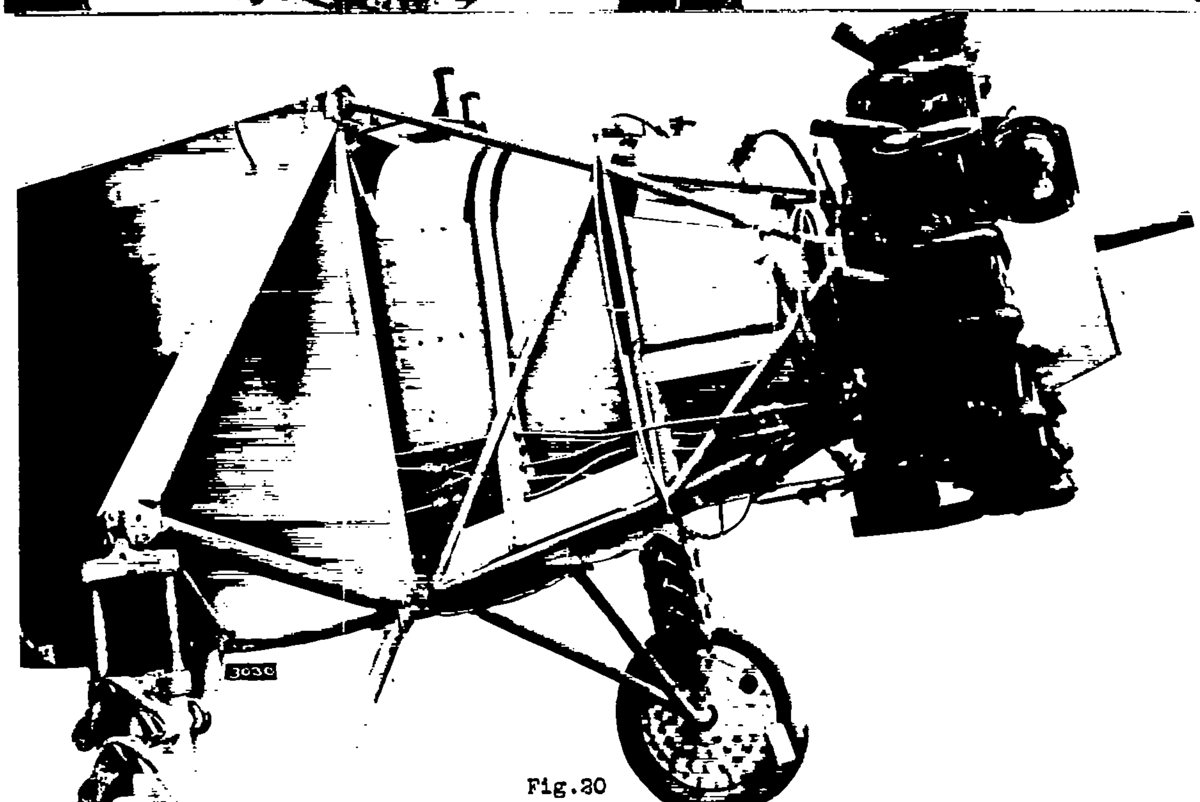

Fig.20

7476 A.S.

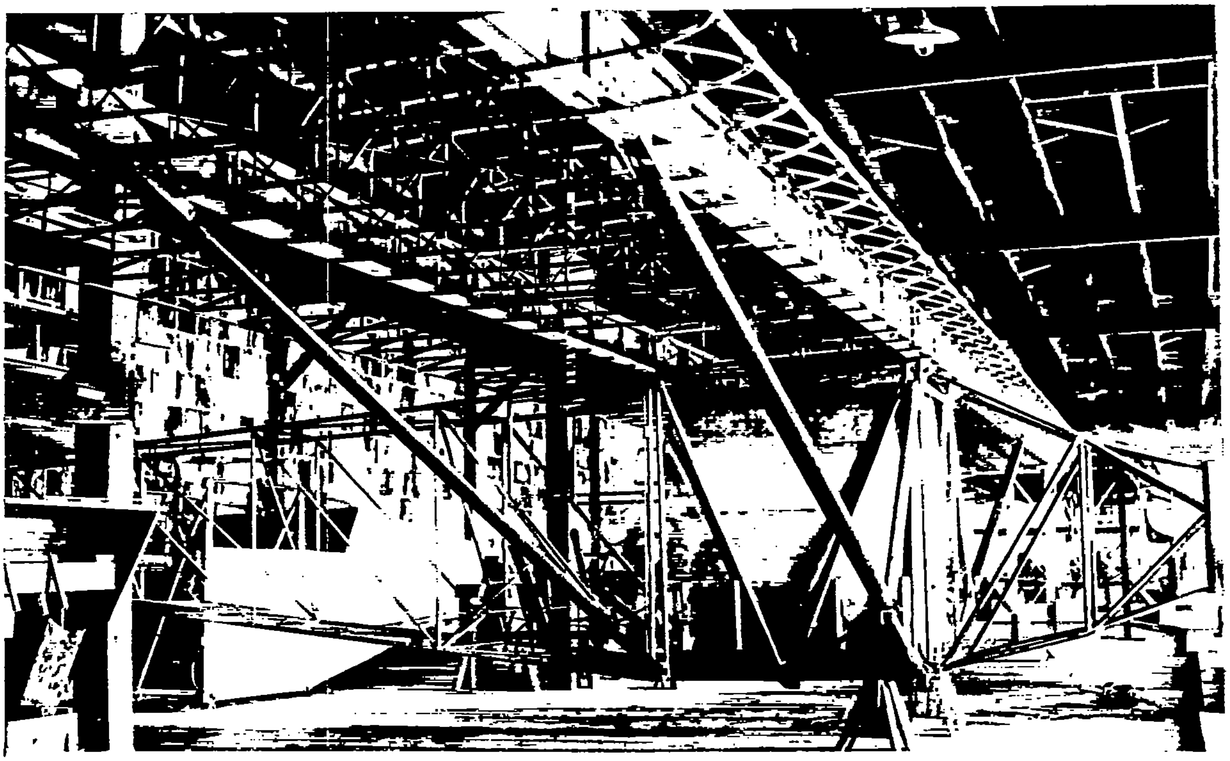

Fig.21

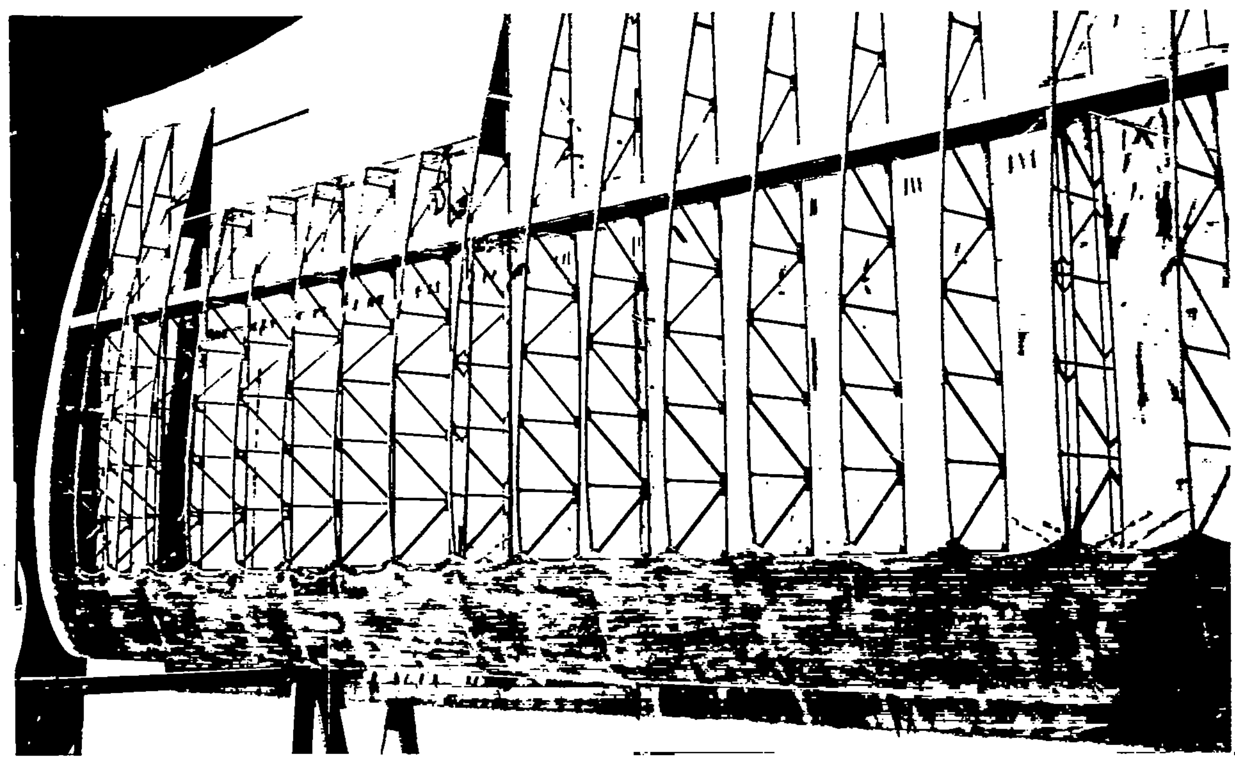

Fig.22

7477 A.S.

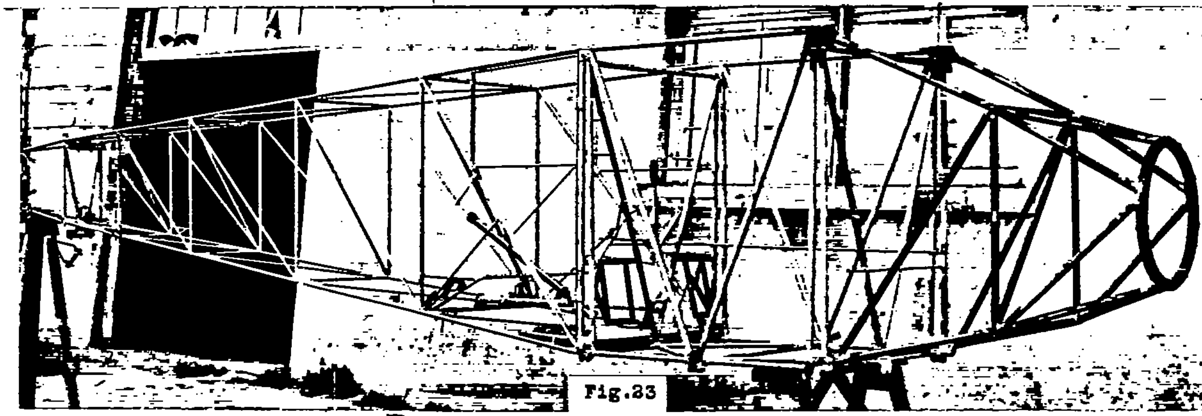

Fig.23

Fig.24

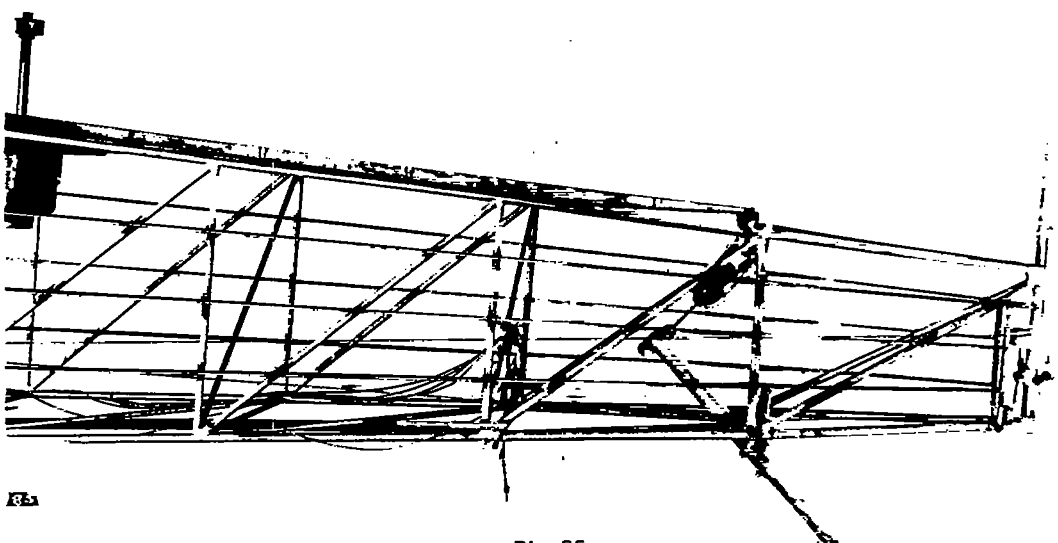

Fig.25

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